Profitable TREE FORMS OF YELLOWPOPLAR

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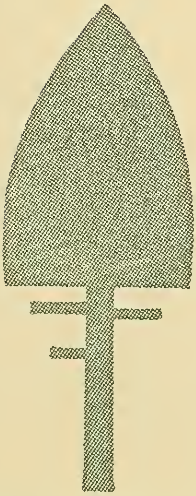

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Profitable Tree Forms of Yellowpoplar

TORKEL HOLSOE

THE OBJECT of most silvicultural management work such as spacing in planting operations and making weeding and intermediate cuttings is to develop trees in such a way that they reach the optimum value in the shortest time. In order to do this, it is necessary not only to know the most profitable development in regard to crown percentage, total height and diameter breast high (d.b.h.) of the mature tree but also to realize the intermediate forms which will bring about this final form.

In all silvicultural management work the forester will need considerable knowledge to foresee the effect of various operations on the development of the individual tree. Knowledge about the effect of weedings, improvement cuttings, and thinnings on the individual tree will be necessary before such operations can be made. Intermediate cuttings that are too light will tend to force up the crown so that it covers only a small part of the total height of the tree, while cuttings that are too heavy will tend to prevent sufficient amounts of clear length to develop. The purpose of the following study is to show the effect of various degrees of liberation on the tree development and the subsequent growth and lumber grades which can be obtained from trees of different forms.

Method of Collecting Data

Yellowpoplar (*Liriodendron tulipifera L.*) was selected because it is one of the important tree species in the Appalachian hardwood region and therefore would show considerable variation in the different lumber grades obtained from individual trees.

The ideal condition for an investigation of this kind would be to have managed stands in which various degrees of intermediate cuttings had been performed during a period long enough for development of trees with a considerable range in crown percentage. This, unfortunately, is not available in the Appalachian region. It was therefore necessary to select individual trees which had a development

that could be compared to the development of trees in stands subjected to various intensities of intermediate cuttings.

Yellowpoplar normally grows on well-drained sites found in coves or on northern exposures in the Appalachian region. Trees which were measured for this study were selected as nearly as possible on the same site. Emphasis was placed on getting as much spread as possible in the crown percentage, thereby simulating the development of trees in stands which had received various degrees of thinnings.

A total of 125 yellowpoplar trees were measured in unmanaged stands in northern West Virginia. On each tree the following measurements were taken: diameter breast high, radial growth during the last ten years, total height, clear length, crown length, crown diameter and, whenever possible, the age of the tree.

Analysis of Data

The relationship between total height and age of yellowpoplar is illustrated in Figure 1. Three curves are shown, the unbroken line being the curve for all data collected. The two broken lines indicate the trend for trees with a crown of more than 40 per cent or less than 40 per cent of the total height, respectively. These two classes were established because they will be characteristic of the development of trees in stands which have been thinned frequently and in stands thinned lightly with long intervals between thinnings. As can be seen from the three curves, there is only slight difference between them. This indicates that the sites for the two classifications are about the same, because density usually does not influence height growth. According to the method of collecting the data, this is what should be expected, since trees of various sizes often grew in the vicinity of each other and the differences in their development was caused only by variances in vigor of neighboring trees. In regard to interpretation of the data given later, these variances are of importance because they show that the more rapid basal area growth and larger crowns are not due to better growing sites but are caused by differences in growing space of individual trees.

The correlation indices for all data, for trees with a crown percentage of more than 40, and for trees with a crown percentage of less than 40 are .820, .845, and .793, respectively (Figure 1). All these indices may be considered highly significant.

In the uneven-aged stand it is often difficult to determine the age of trees. Furthermore, in many intermediate cuttings, trees of the

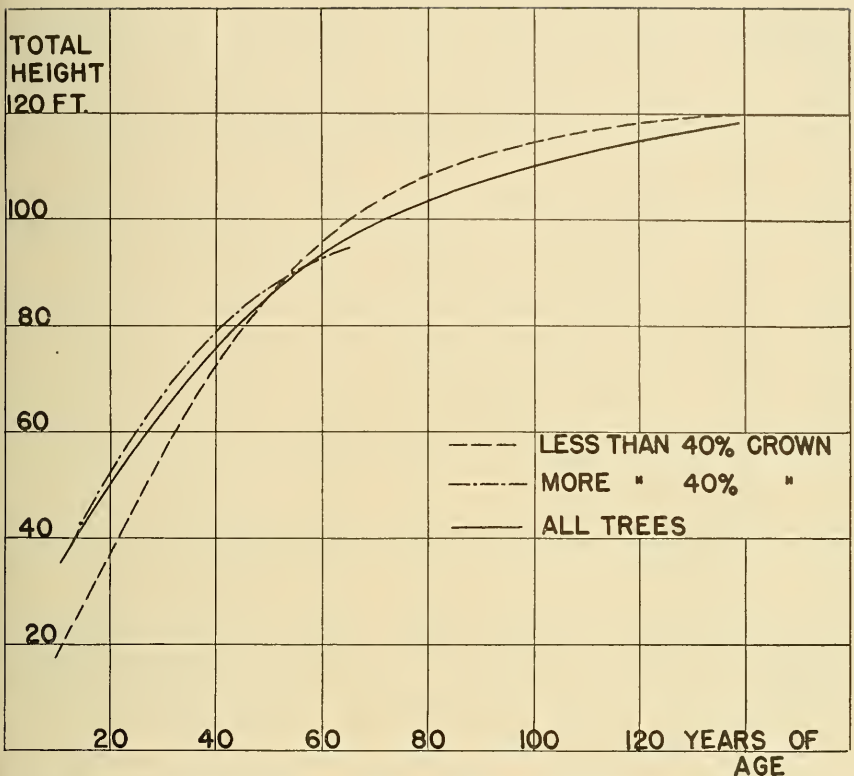


FIGURE 1. Relationship between total height and age.

intermediate crown class are often favored because they frequently have better form and show less coarseness than the dominant trees. The latter often have had considerable expansion possibilities while they were young and therefore have developed large low-placed branches which will leave large scars and produce low-grade lumber after they die. Although there may be a reduction in the average d.b.h. of the stand by such intermediate cuttings, the average total height usually will not be changed. For this reason, the following relationships have been based on total height rather than age. Furthermore, total height can be measured more readily. In the uneven-aged forest it is not uncommon for reproduction groups to stay for a long time in partial shade. These will not grow as fast as trees that have had more light. Such trees which have been "kept in storage" for later use will have an age which proportionately is much higher than if they had not been held back. The rate of interest with which these trees grow will

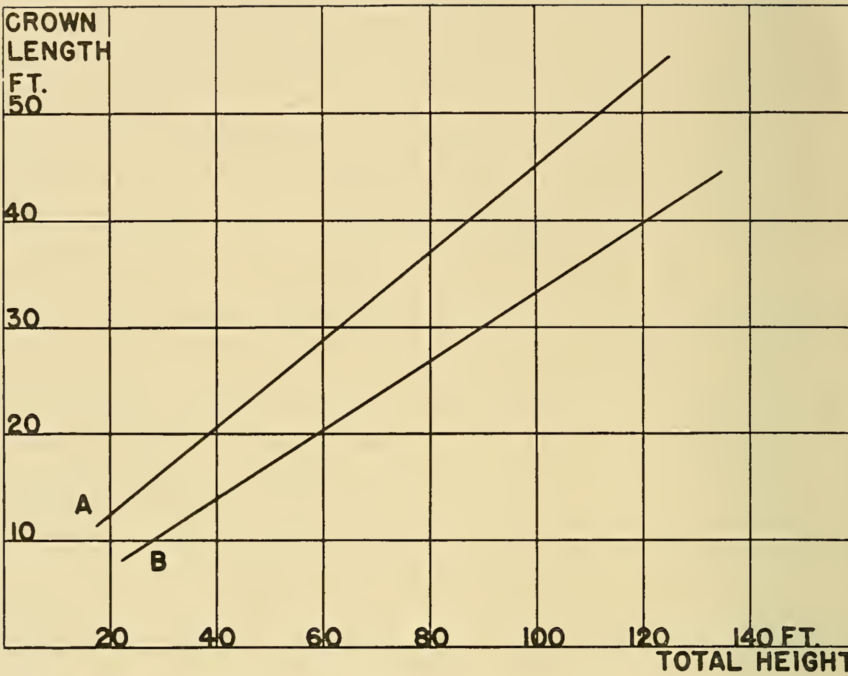


FIGURE 2: Relationship between crown length and total height.

not be of importance until they are released and start to develop their normal height growth. They have been developed with little or no expense and should not be charged for the time they have been held back while financial returns were obtained from the trees which shaded them.

The relationship between crown length and total height is shown in Figure 2. Correlation coefficients of the curves for trees with more than 40 per cent crown and less than 40 per cent crown are .899 and .804, respectively. The trend of the curves in this relationship will naturally be dependent upon the trees selected. The interest, however, lies in the fact that it is possible in the unmanaged stands to find a considerable spread in crown length. This means that even with a rather intolerant species such as yellowpoplar no difficulty will be encountered with the development of deep crowns in managed stands.

The relationship between crown diameter and total height is shown in Figure 3. Correlation coefficients of the curves for trees with more

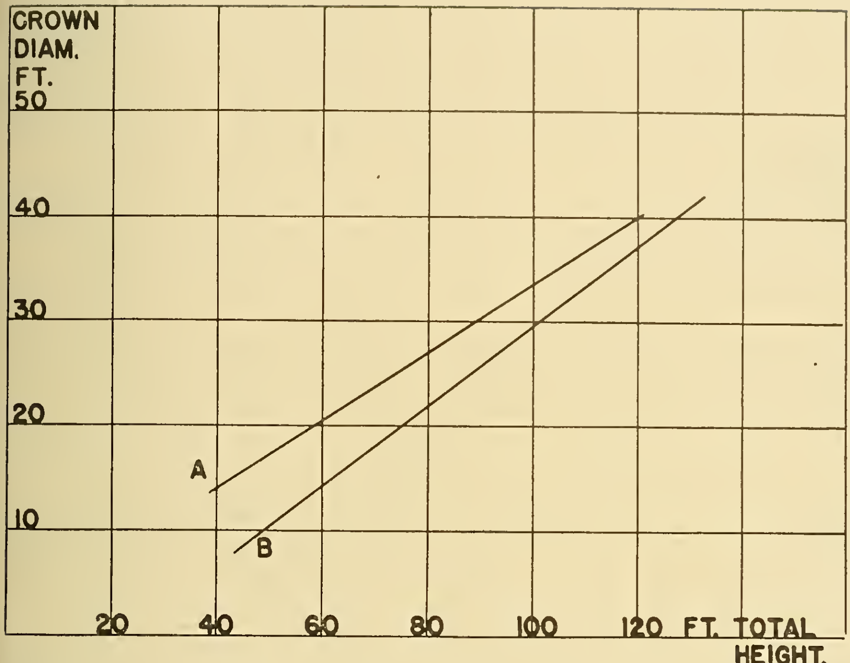


FIGURE 3: Relationship between crown diameter and total height.

than 40 per cent crown and less than 40 per cent crown are .856 and .816, respectively. No great difference is found between the two curves because of the rather cylindrical shape of the lower part of the crown. Increasing length of crowns will show only a slight increase in crown diameter.

The relationship between d.b.h. and total height which is shown in Figure 4 brings out the reaction of the two crown percentage classifications. Correlation indices of the curves for trees with more than 40 per cent and less than 40 per cent crown length are .916 and .791, respectively. Although the average crown percentages for the two classifications only show a relatively small difference, namely 46.4 and 33.4, there is considerable variation in the d.b.h. growth as related to height. For instance, at a total height of 50 feet the difference is 1½ inches, while at 100 feet the difference is 4 inches. Such increased diameter growth is entirely due to the difference in the size of the crown inasmuch as all trees have been taken from the same site as indicated in Figure 1.

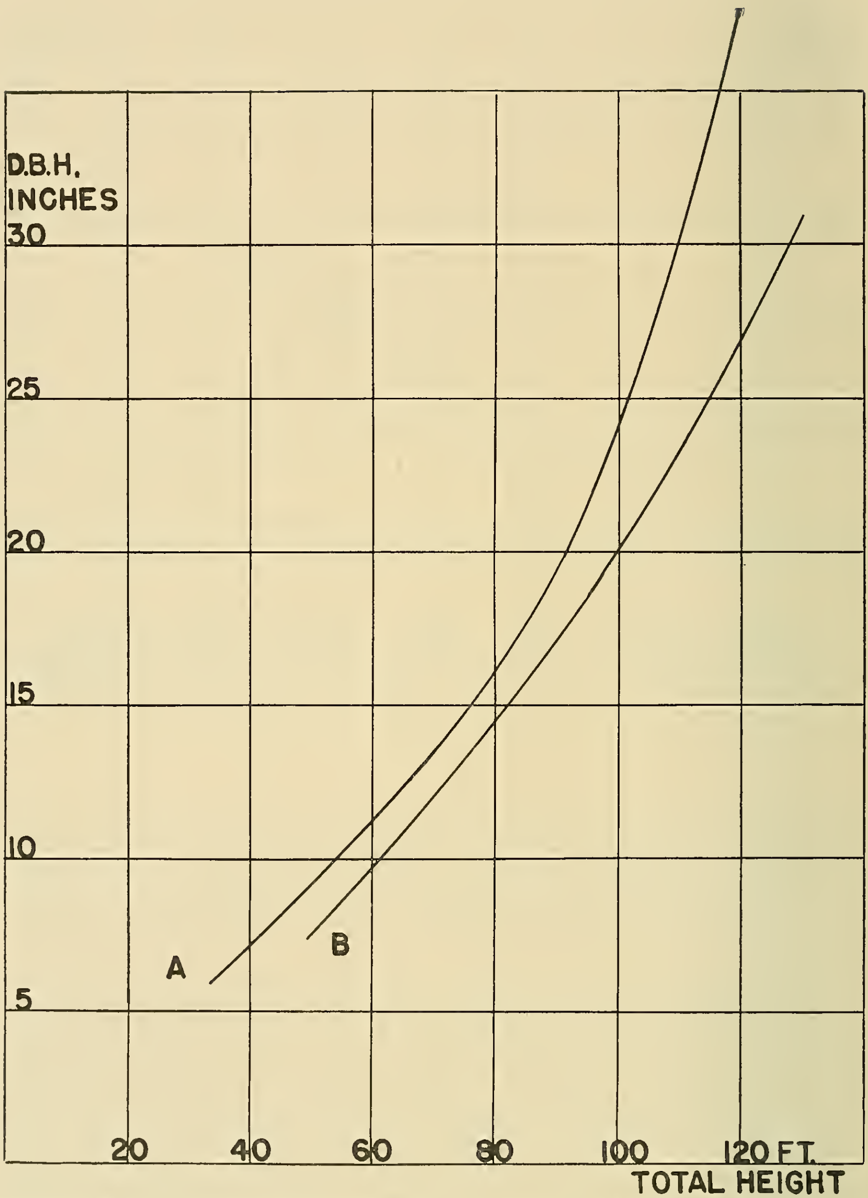


FIGURE 4: Relationship between d.b.h. and total height.

The relationship between clear length and total height is shown in Figure 5. Correlation indices for trees with more than 40 per cent

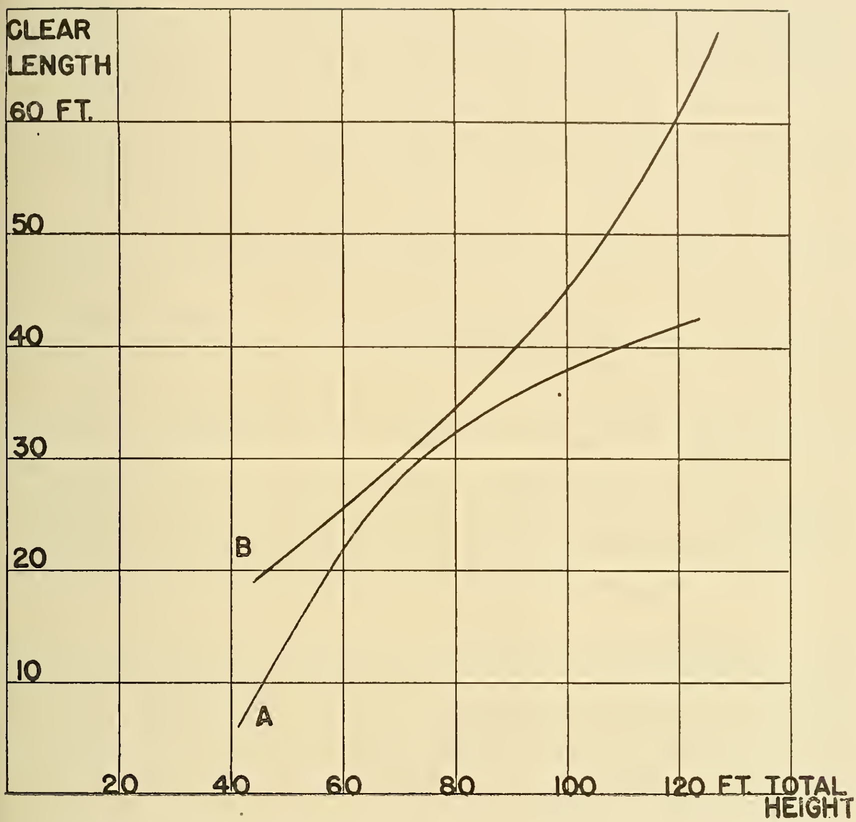


FIGURE 5: Relationship between clear length and total height.

crown and less than 40 per cent crown are .856 and .630, respectively. Trends of the two curves are significant. On trees with more than 40 per cent crown the clear length development tapers off and will be asymptotic to the total height, while on trees with less than 40 per cent crown the clear length development will continue although the total height growth stops. At a total height of 80 feet the difference between the two curves is only 4 feet; at 120 feet there is a difference of 29 feet between the clear length development of the two classifications of trees. On the other hand, during this period the tree with a crown percentage above 40 has grown 33 per cent more on the diameter compared to the tree with less than 40 per cent crown, as may be determined from Figure 4. The latter has grown only 6 inches on the radius which means that at a point 33 feet above the ground there

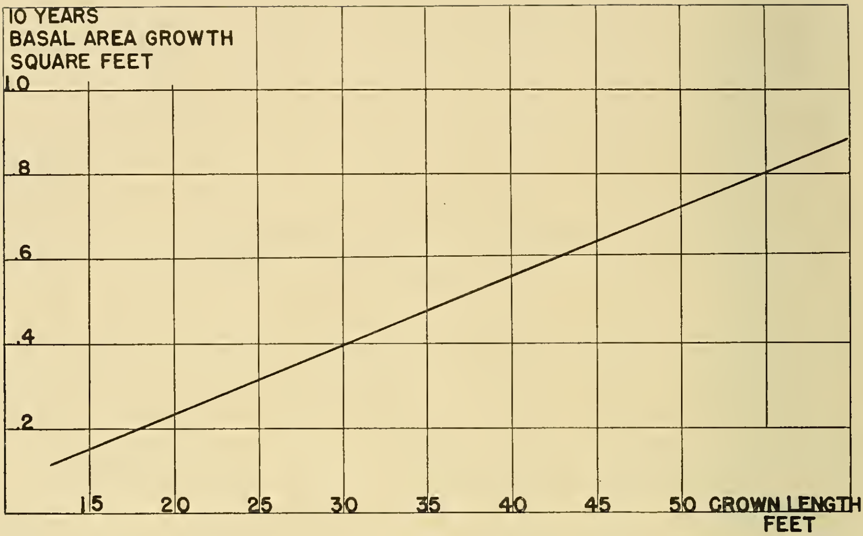


FIGURE 6: 10-year growth of basal area, related to crown length.

will be only 6 inches of clear wood outside the knotty core. The amount of clear wood above this point will be steadily decreasing until it reaches zero at 60 feet where no clear wood is present. Development of clear length beyond 33 feet or two 16-foot logs will not add much high grade lumber to the upper logs unless the tree is grown to extremely large dimensions.

Influence of Crown Dimensions on Growth

By means of the preceding figures, illustrations have been made of the development of yellowpoplar showing how various dimensions develop as related to total height. The next question to be investigated is the relationship between various crown dimensions and growth. The best relationships could probably be obtained by relating crown dimensions with volume growth. Volume growth, however, is difficult to measure because it not only necessitates measuring the difference of basal area within a certain interval but also requires measuring height growth during the same period.

Basal area therefore was used in the two following relationships to indicate growth as it is related to development of the crown. Figure 6 shows the relationship between ten years' basal area growth and

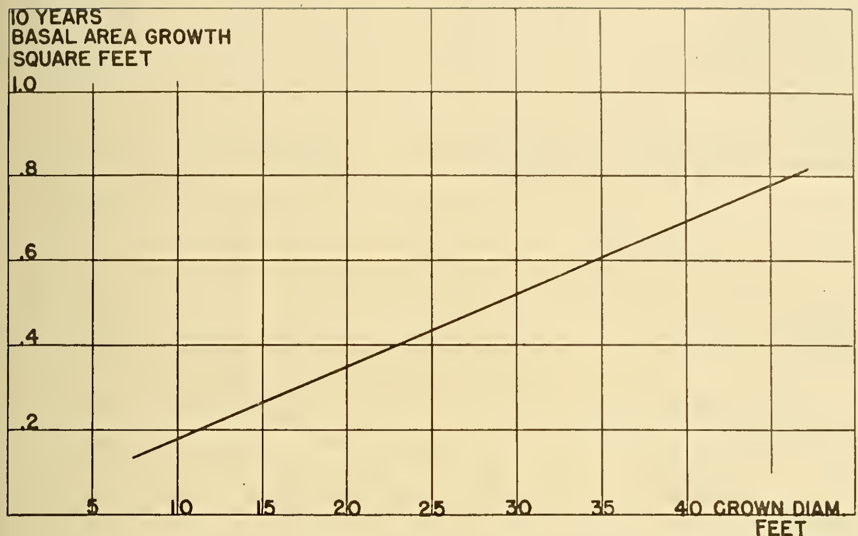


FIGURE 7: 10-year growth of basal area, related to crown diameter.

crown length. The correlation coefficient for this relationship is .743. This shows that more than 50 per cent of the variance is accounted for in this relationship. It may be determined that if a crown length of 50 to 60 per cent is developed, trees which are about 65 years of age and, according to Figure 1, have reached about 100 feet total height will produce about .8 square foot of basal area in ten years. This can be seen from Figure 6. With adequate thinnings giving continuous space for maintaining such a crown, continued maximum growth can be maintained.

The relationship between ten years' basal area growth and crown diameter is shown in Figure 7. The correlation coefficient is .796, which indicates that the relationship is highly significant. The correl-tion coefficient is slightly higher than the one obtained for Figure 6. This is what can be expected since the crown diameter usually is better defined. The data for this dimension were obtained by measuring two crown diameters at right angles to each other. Crown length, however, is sometimes difficult to determine because the crown may be deeper on one side than the other. In such cases an average was determined to which the length was measured. Furthermore, the shell of leaves on the lower part of the crown is much thinner than on the upper part. For that reason a certain amount of inaccuracy is included in the measurement. On the other hand, in measuring

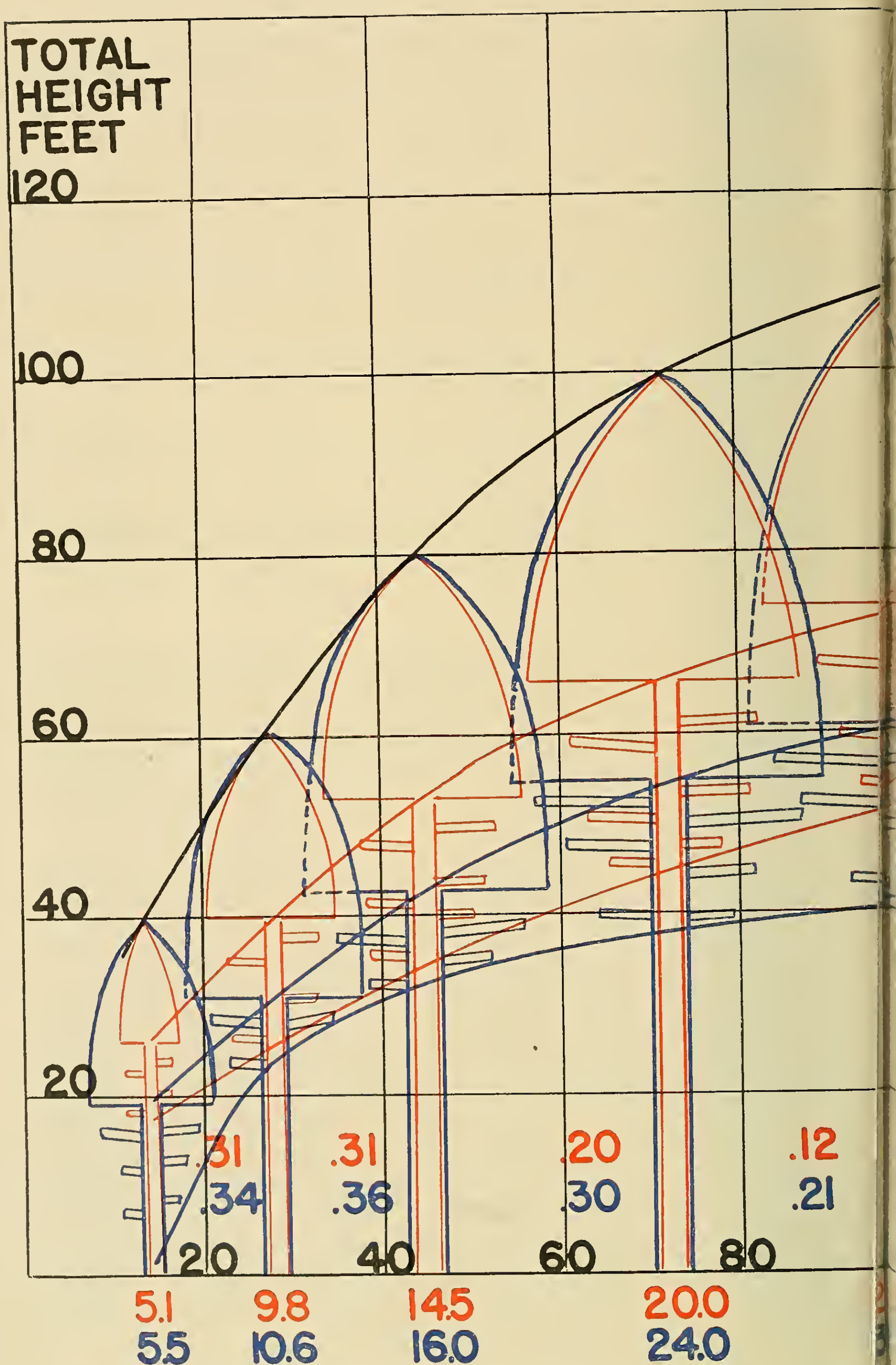
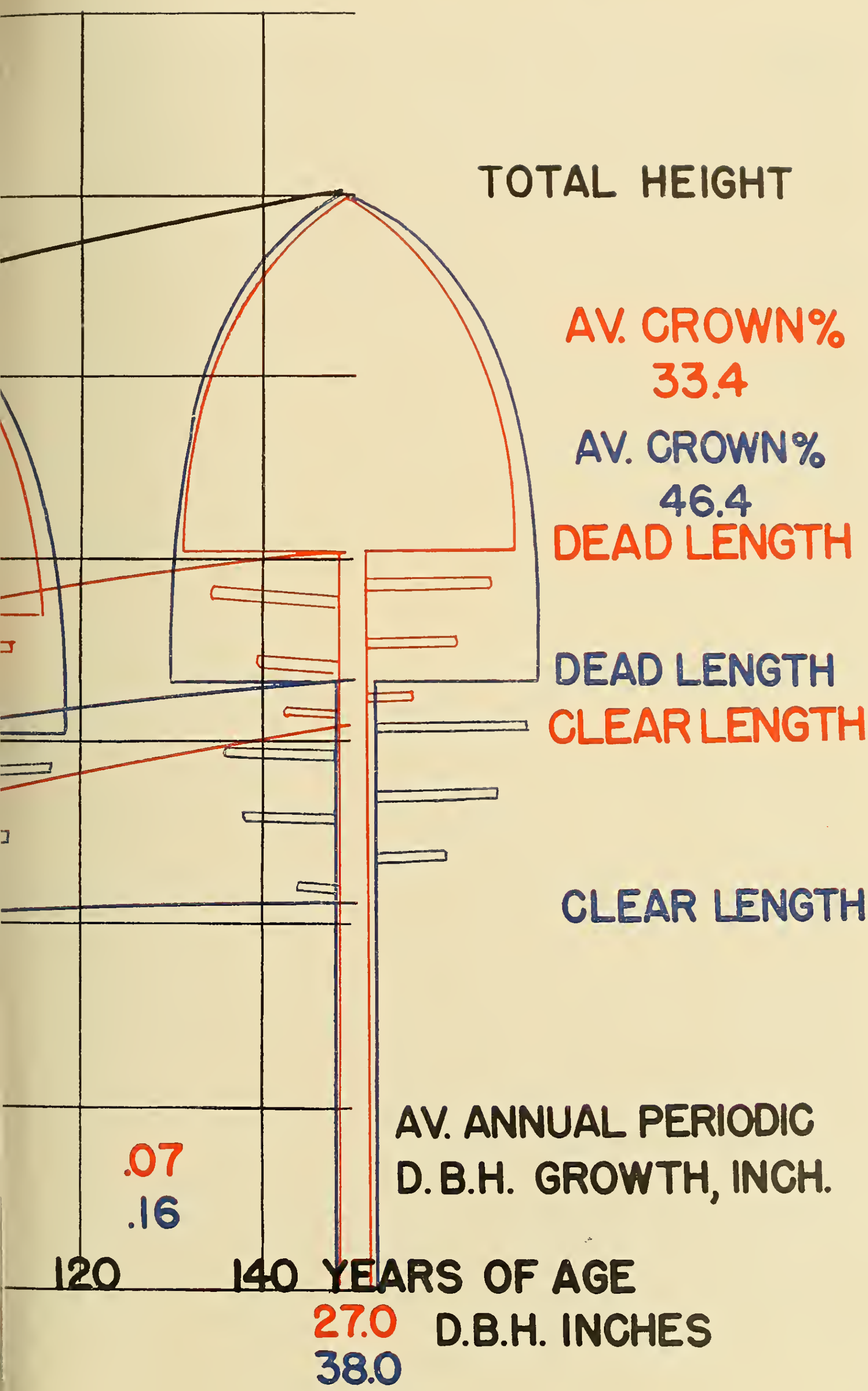


FIGURE 9: Development of yellowpoplar shown in graphic form.


TOTAL HEIGHT
AV. CROWN%
33.4
AV. CROWN%
46.4
DEAD LENGTH
DEAD LENGTH
CLEAR LENGTH
CLEAR LENGTH
AV. ANNUAL PERIODIC
D. B.H. GROWTH, INCH.
.07
.16
120
140 YEARS OF AGE
27.0 D.B.H. INCHES
38.0

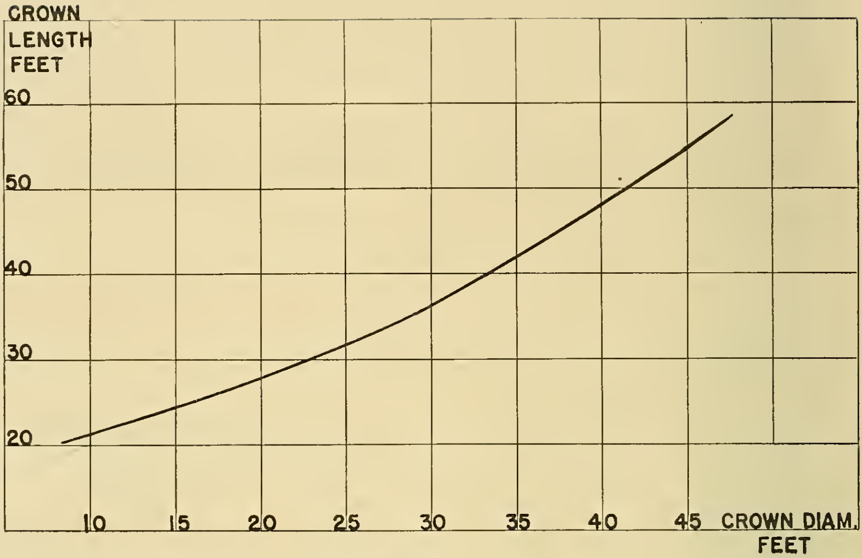


FIGURE 8: Relationship between crown length and crown diameter.

the crown diameter this inaccuracy does not enter since the same proportional amount of thin and heavy layer of leaf surface is included in the measurement.

The relationship between crown length and crown diameter is shown in Figure 8. The high correlation index of .805, which indicates that 65 per cent of the variance between the two variables is accounted for, shows that for a certain crown diameter there is a corresponding crown length. Hence, the form of the crown is rather definite and by using one of the factors, either crown length or crown diameter, an expression for the entire crown can be obtained. Further calculations have been done in regard to crown surface[1] and its relationship to basal area growth. But inasmuch as the formula for crown surface is determined by crown length and crown diameter, no further help is obtained for practical management.

Comparing Figures 6, 7, and 8 it will be found that the basal area growth checks very well using as entries either crown length or crown diameter. Usually crown length is easier to estimate ocularly. Because of that, this dimension is to be preferred for practical work.

Development of the two classifications is shown in graphic form in Figure 9. From Figure 1 the curve of height over age has been

[1] Torkel Holsoe, "Crown Development and Basal Area Growth of Red Oak and White Ash," *Harvard Forest Papers*, (Harvard Forest, Petersham, Massachusetts, 1948), 1: 27-34.

transferred to Figure 9. Height growth was about the same for the two crown classifications and therefore has been indicated by one line only. Curves for the dead length and clear length are indicated in red for the trees with an average crown percentage of less than 40 and in blue for trees with more than 40 per cent crown. The averages for these two classifications show that the first group has an average crown percentage of 33.4, while the average for the second group is 46.4.

Data for the dead length curves have been obtained from Figure 2 by subtracting the crown length from the total height. Data for clear length have been obtained from Figure 5. The crown dimensions have been drawn to scale, the crown diameters having been obtained from Figure 3. The diameters breast high have been obtained from Figure 4 and are indicated below each of the trees drawn. The average annual periodic d.b.h. growth has been obtained from these diameters, taking into consideration the interval in years between the trees drawn in the figure. Figure 9 shows that at 100 years of age the trees with 33.4 per cent crown have a clear length of 52 feet and a dead length of 74 feet; trees with an average crown percentage of 46.4 have a clear length of 40 feet and a dead length of 61 feet. Trees with the smaller crown percentage have 12 feet more clear length than trees with a larger crown percentage.

In order to investigate what this will mean in the amount of clear wood placed outside the knotty core, it can be observed that the red curve for clear length reaches a height of 33 feet or the base of the third 16-foot log at an age of 42 years. Between 42 and 100 years of age the tree grows 9.7 inches in diameter. This will mean that the base of the third log will have a shell of clear wood 4.9 inches thick outside the knotty core. By following the same procedure for the top of the third log or 49 feet above the ground, it is found that this part of the tree is included in the clear length at an age of 88 years. Diameter growth for the next 12 years amounts to 1.44 inches. This means that the shell of clear wood at the top of the third log will be about .7 inches for trees with an average crown percentage of 33.4. It is therefore questionable if it will be possible to saw out any boards of high grade from the amount of clear wood outside the knotty core. By developing this extra log with clear length, the diameter growth is reduced so that during the time the third log is being developed these trees grow 9.7 inches. Trees with the crown percentage of 46.4 grow 15.1 or 5.4 inches more on the d.b.h. Investigating the second 16-foot log for trees with 33.4 per cent crown, it is found that the large end of this log is cleared when the tree

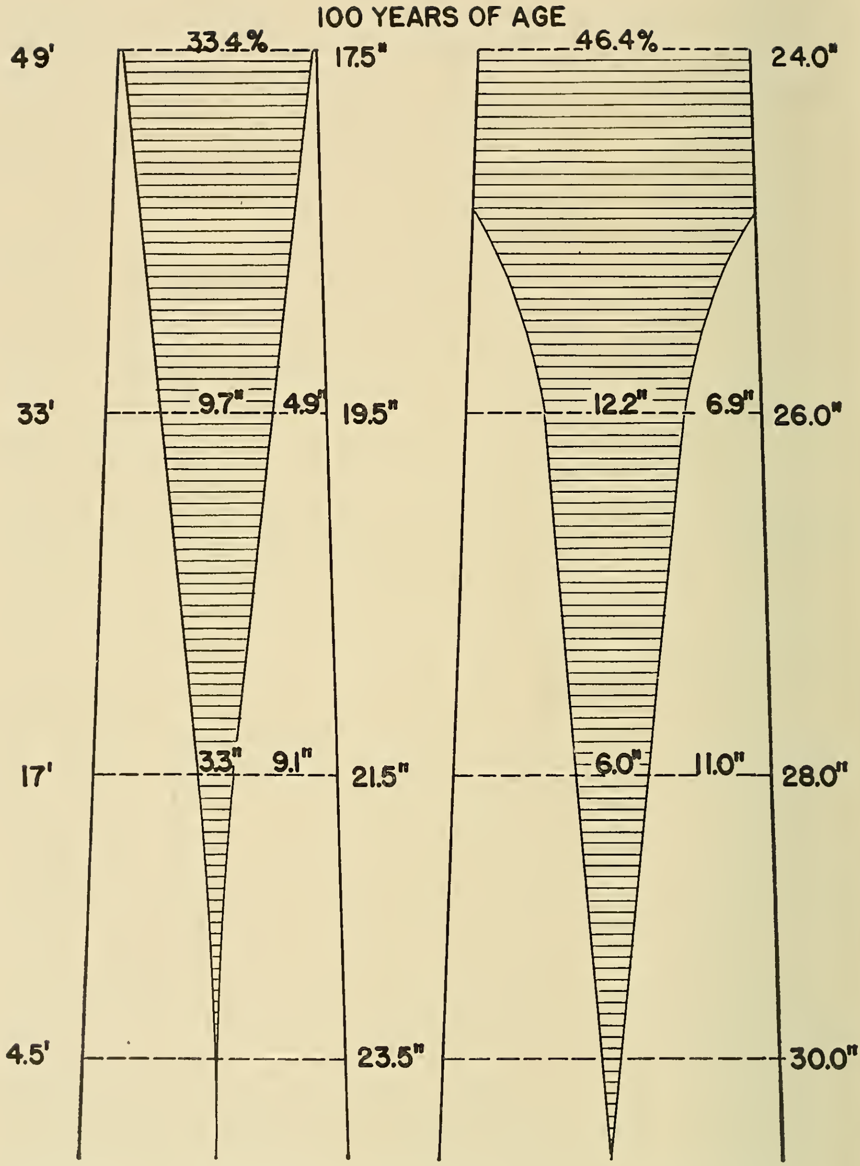


FIGURE 10: Yellowpoplar 100 years old. Knotty core shaded.

is 14 years old. During the next 86 years the tree grows 9.1 inches on the radius. Because of that fact, the log has a shell of clear wood which is 9.1 inches at the base and tapers off to 4.9 inches at the top.

Table 1. Yellowpoplar 100 Years of Age

LOG	LENGTH	VOLUME				
		Clear Wood		Knotty Wood		Total Board Feet
		Bd. Ft.	Percentage	Bd. Ft.	Percentage	
46.4% Crown						
	feet					
1st	17	615.4	98.5	9.6	1.5	625.0
2nd	16	400.0	80.0	100.0	20.0	500.0
3rd	16	29.0	7.0	396.0	93.0	425.0
Total	49	1044.4	67.5	505.6	32.5	1550.0
33.4% Crown						
1st	17	359.3	99.5	1.7	0.5	361.0
2nd	16	234.0	85.1	41.0	14.9	275.0
3rd	16	45.4	21.0	171.6	79.0	217.0
Total	49	638.7	75.0	214.3	25.0	853.0

Trees with an average of 46.4 per cent crown have 33 feet or two 16-foot logs of clear length at an age of 46 years. At that time the d.b.h. is 16.3 inches. During the next 54 years the diameter increases to 30 inches at 100 years of age, which means that the shell of clear wood at the top of the second log is 6.9 inches thick. The base of the second log at 17 feet above the ground is clear of branches at an age of 22 years. At this time the d.b.h. is 8.0 inches. The d.b.h. at 100 years is 30.0 inches. This means a radial increase of 11.0 inches, which will be the thickness of the shell of clear wood outside the knotty core.

Figure 10 shows this development graphically and in Table 1 the percentage and volume of the clear wood is given. In order to obtain the d.b.h. of 30 inches it would be necessary to grow trees with the crown percentage of 33.4 to an age of about 185 years. Although the trees at that age would have slightly more clear wood than the trees with the larger crown percentage at an age of 100 years, the gain will far from compensate for the 85 years it would be necessary to keep them.

This analysis shows that it is highly uneconomical to develop more than two clear logs. In managing stands of yellowpoplar, the criterion should be to develop two clear logs as soon as possible.

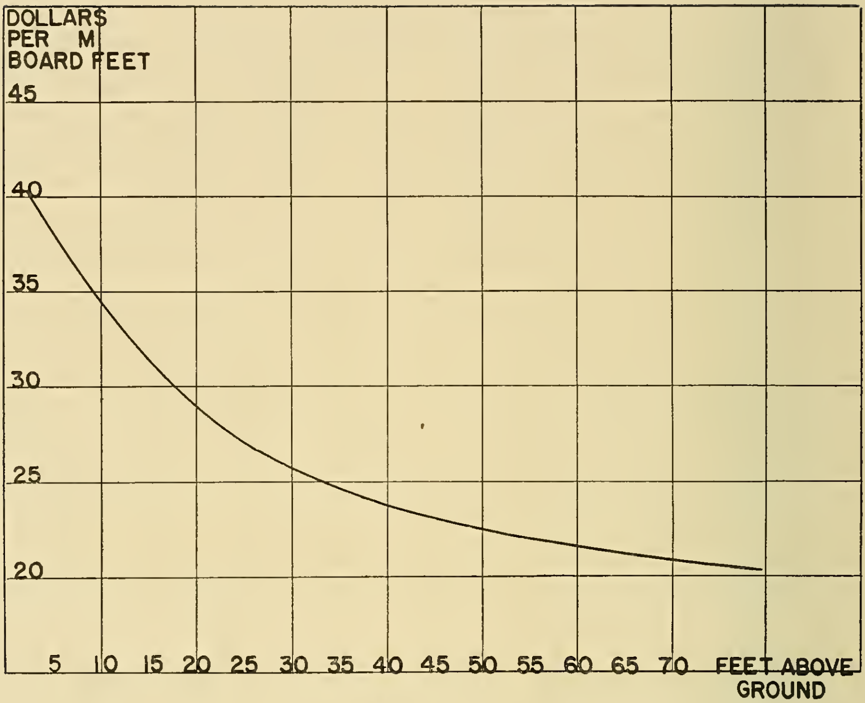


FIGURE 11: Relationship of $ per M bd. ft. to height above stump.

During the time of development, however, it is important to maintain a crown length between 33 and 50 per cent of total height. Otherwise the trees will have a tendency to stagnate in height growth. As soon as the two clear logs have been developed the primary purpose of the silvicultural management should be to maintain live branches above the clear length in order to avoid the section with dead branches. Nothing is gained from the section with dead branches, which will have a tendency to develop lumber with black, loose knots. If the branches are kept alive they will add to the assimilation and increase the diameter growth of the tree. Furthermore, they will produce lumber of higher grade since live branches will produce lumber with green, tight knots. At an age of 85 years, such trees will have 60 per cent or more crown. These trees can be developed only by thinnings which release the crowns; frequently they suffer interference from neighboring trees. It can be expected that such trees will have an even better diameter growth than the ones shown with a 46.4 per cent crown in Figure 9.

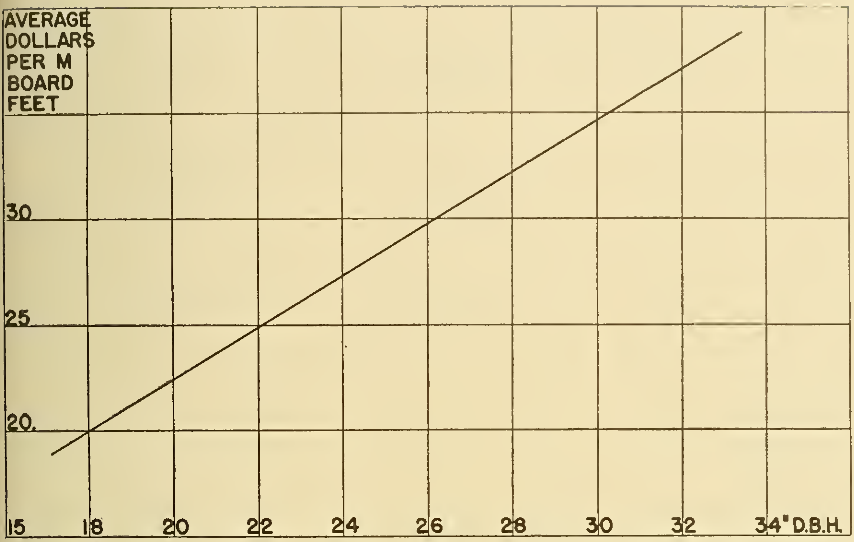


FIGURE 12: Relationship of average $ per M bd. ft. to d.b.h.

Value of the Individual Tree

In order to investigate the amount of lumber of various grades which can be sawed from yellowpoplar trees, 37 trees were examined. The logs were marked as the trees were cut in the woods. On arrival at the sawmill they were followed through, and the volume was determined for each log in the standard lumber grades. Since this work was done during 1941-42, the current prices for that period were used for the various lumber grades. They were as follows: Firsts and Seconds — $70, Saps — $50, Number 1 Common and Select — $37, Number 2A Common — $27, and Number 2B Common — $18. Although prices have advanced considerably since then, relative values of the various grades are almost the same. Prices are ranging between 2.7 and 3.4 times those of 1942. The values of 1942 have, for that reason, been used in Figure 11. It gives for yellowpoplar the price per thousand feet board measure related to feet above the stump.

From Figure 11 it can be seen that the price per thousand feet board measure at 8 feet above the stump or, in other words, the value of the first log, is about $36. The value of the second log is $27.50, the third log $23.75, and the fourth log $22. By far the greatest values are obtained from the first two logs. The correlation index for the curve in Figure 11 is .769 which may be considered highly significant.

Table 2. Dimensional Development of Yellowpoplar

Age	Development									
	Total Height	D.B.H.	Dead Length	Clear Length	Crown Diam.	Crown Length	Crown Length	Volume Dead Length	Value M bd. ft.	Total Value
2-Log Trees* — 46.4% Crown										
years	feet	inches	feet	feet	feet	feet	%	bd. ft.	$	$
20	49	8.8	25	16	17	24	49			
30	63	11.8	32	23	21	31	49	62		
40	75	14.6	40	28	26	35	47	149	17.60	2.62
50	85	17.6	46	32	29	39	46	291	22.40	6.68
60	93	20.6	51	35	31	42	45	516	27.40	14.10
70	99	23.4	54	37	33	45	45	778	31.90	24.80
80	104	26.2	57	38	35	47	45	1068	35.50	37.90
90	107	28.0	59	39	36	48	45	1250	38.20	47.70
100	110	30.0	61	40	37	49	45	1424	40.20	57.20
3-Log Trees*—33.4% Crown										
20	49	7.4	32	21	10	17	35			
30	63	10.5	42	22	15	21	33			
40	75	13.3	50	31	20	25	33	131		
50	85	15.8	57	37	24	28	33	261	19.90	5.18
60	93	18.0	62	41	27	31	33	404	23.30	9.40
70	99	19.8	66	44	29	33	33	559	26.20	14.65
80	104	21.4	69	47	31	35	34	698	28.30	19.80
90	107	22.4	72	50	32	35	33	814	29.90	24.30
100	110	23.5	74	52	33	36	33	900	31.00	27.90

* 16-foot logs at twenty inches d.b.h.

Relating these values to the d.b.h. of the various trees, it is now possible to find how the value per thousand feet board measure increases with an increase on the diameter. Figure 12 expresses this relationship as a straight line.

The correlation coefficient obtained from the equation is .599 which for thirty-five data is considered significant.

From Figures 9 and 12, it is now possible to formulate Table 2, which gives the development and value of yellowpoplar at various ages. Table 2 shows the development of trees which have two or three clear logs when approximately 20 inches d.b.h. is reached. Such trees have an average crown percentage of about 46.4 and 33.4, respectively.

From these tables it can be seen that approximately the same value can be obtained on a two-log tree in 70 years as can be produced on a three-log tree in 100 years. This again emphasizes the conclusion reached in regard to diameter growth, that it pays to develop two logs of high-grade material rather than to keep the stand dense and thereby develop more clear logs which usually have an inferior quality.

By means of Table 2, and by using the curves for total height over age for the two crown percentage classifications, it is possible to construct tables which give the compound interest rate of growth based on radial increment and d.b.h.[2] Since there is a difference between the volume of two-log and three-log trees and since the value per thousand board feet is not the same for trees with the same d.b.h. in the two classes, it is necessary to establish a table with two sections; one for trees with 46.4 per cent crown or two clear 16-foot logs at 20 inches d.b.h. and another for trees with 33.4 per cent crown or three 16-foot logs at 20 inches d.b.h.

Conclusions

Yellowpoplar, being one of the fastest growing commercial timber species. in the Appalachian region, lends itself well to intensive silvicultural management practices. If stands of this species are located close to roads making the stands accessible and if favorable markets are available, it will be profitable to manage yellowpoplar intensively.

Intensive practices should be started early, thereby allowing development of deep crowns. The aim should be to keep the stands reasonably dense until about two 16-foot logs have been developed as dead

[2] Torkel Holsoe and F. Muus, "Economical Considerations," *Dansk Skovforeninus Tidsskrift,* (Copenhagen, Denmark, 1930), pp. 145-164.

Table 3. Compound Interest Rate of Periodic Growth

D.B.H.	GROWTH RATES (Represent 10 years' growth on radius)												
	.4 in.	.6 in.	.8 in.	1.0 in.	1.2 in	1.4 in.	1.6 in.	1.8 in.	2.0 in.	2.2 in.	2.4 in.	2.6 in.	2.8 in.
2 Clear Logs*—46.4% Crown													
	%	%	%	%	%	%	%	%	%	%	%	%	%
12	2.2	3.4	4.5	5.9									
14	2.0	3.1	4.2	5.4	6 5	7.5							
16	1.8	2.8	3.8	4.9	6.0	6 9	7.9	9.0	10.0	11.0	11.9		
18	1.7	2.6	3.5	4.5	5.5	6.3	7.2	8.3	9.4	10.4	11.4	12.4	
20	1.5	2.3	3.1	4.0	4.9	5.7	6.6	7.6	8.6	9.6	10.6	11.6	12.5
22	1.3	2.0	2.8	3.6	4.4	5.1	6.0	6.8	7.7	8.6	9.7	10.6	11.5
24	1.2	1.8	2.5	3.2	3.9	4.6	5.4	6.1	6.9	7.7	8.5	9.4	10.3
26	1.0	1.5	2.1	2.7	3.3	4.0	4.7	5.3	6.0	6.6	7.3	8.1	8.8
3 Clear Logs*—33.4% Crown													
12	1.8	2.8	3.8	4.8	5.9	7.0	8.2	9.3	10.5				
14	1.8	2.8	3.8	4.8	5.8	6.9	8.0	9.1	10.3	11.4			
16	1.7	2.7	3.7	4.7	5.6	6.6	7.7	8.7	9.8	10.9	11.9		
18	1.7	2.6	3.5	4.4	5.3	6.3	7.4	8.3	9.3	10.3	11.3	12.3	13.3
20	1.6	2.5	3.3	4.2	5.1	6.0	6.9	7.8	8.7	9.6	10.6	11.6	12.6
22	1.4	2.2	3.0	3.8	4.6	5.4	6.3	7.1	7.9	8.8	9.8	10.8	11.7
24	1.2	1.9	2.6	3.4	4.1	4.8	5.6	6.4	7.2	8.0	8.9	9.8	10 7
26	.8	1.5	2.2	2.8	3.5	4.1	4.8	5.5	6.2	7.0	7.8	8.7	9.5

* Computed for logs at 20 inches d.b.h.

length. During this time, however, it will be advisable to maintain a crown which will cover approximately half of the total height. After this dead length has been obtained, the object will be to keep alive any branches above the two logs. It can be done only through repeated thinnings made as soon as the crowns of the individual trees start to touch their neighbors. As soon as this happens, friction will start to wear off the fine branches, which will cause a reduction in growth.

The forester should be aware of the fact that even if the trees do not touch each other on quiet days, much damage may be done on windy days when movements of the crowns are heavy. In stands managed with many intermediate cuttings, however, it is possible to develop sturdy trees which will have less movement than trees in unmanaged stands where the stems usually have a more slender form. Through repeated thinnings, it will be possible to develop trees which at a total height of 100 feet will have a crown length of about 60 feet. Such trees will show a much faster growth than has been indicated in Table 2. They will reach merchantable timber sizes in much shorter time and maintain a much better compound interest rate than indicated in Table 3.

Through this increased rate of growth such intensive measures on readily accessible areas will prove to be highly profitable. Through such management it will be possible to obtain current annual increment during the last half of the rotation which will be close to a thousand board feet per acre. Based on available stumpage prices of yellowpoplar, these stands in many cases will produce more net revenue than some areas in use for agricultural purposes such as pastures. It will therefore be of definite value to investigate stands with considerable component of yellowpoplar for the purpose of evaluating the financial returns which can be obtained from intensive practices.